Numeracy and the quality of on-the-job decisions: Evidence from loan officers

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Motivation

14 high-paying jobs for people who love math

Jacquelyn Smith, Business Insider  
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Does the idea of crunching numbers and sifting through data all day excite you?

You're probably a "math person" — and you may want to consider pursuing a job that requires these skills.

Turns out, a lot of math-centric jobs pay pretty well.
This paper

Do employees with stronger numerical skills perform better on the job?

Are loan officers with stronger numerical skills more accurate in assessing the creditworthiness of loan applicants?

- Loan officers with high numeracy levels are more accurate in assessing the creditworthiness of small business borrowers
- The effect of numeracy is strongest in the pre-crisis lending boom
Numeracy is....

LOAN DEPARTMENT

“the ability to understand and work with numbers” and “do logical reasoning”

4000 x 0.7 = 2800
2800 x 25% = 700
700/12 = 58\frac{1}{3}
... is more than just math

• Individuals with higher numeracy seem...
  • to draw stronger meaning from numbers (Peters et al. 2006)
  • less prone to framing effects (Peters et al. 2006)
  • more able to anticipate social behavior (Burks et al. 2009)

• Numeracy is associated with risk taking and intertemporal decision-making
  • less averse to take calculated risk (Burks et al. 2009)
  • more patient (Frederick 2005; Burks et al. 2009)
The bank

- Romanian commercial retail lender
  - Subsidiary of international group
  - Branches countrywide

- Focus on small businesses and households
  - Credit portfolio dominated by small business loans of less than 30,000 EUR
Why small business lending?

• Loan officers have substantial discretion in assessing the creditworthiness of borrowers
  • Verify quantitative information
  • Elicit qualitative information
  • Interpret the quantitative and qualitative information

• We observe a large number of comparable decisions
  • The quality of the credit assessment can be measured
  • ... and is thus comparable across employees
The lending process

- Application in branch
- On site visit
- Risk score calculation
- Loan suggestion
- Credit committee decision

• Verify quantitative info
• Assess collateral value
• Elicit qualitative info

• Interpret information
• Propose and decide upon loan terms
The math test

• Headquarter decision
  • Implemented in all subsidiaries worldwide
  • Conducted in 2010/02 at short notice

• Comparable to high school math

1. Calculate the value of the following expressions. [3.3]

\[
\frac{\left(\frac{3}{4} + 2\right)}{2 \cdot 3 - 2 \cdot (-6) - 7} =
\]

(3 pts. for each correct answer)

3. Six friends want to buy a piece of land, each paying an equal share. The day before the contract is signed two of the friends decide to withdraw their offer. The remaining four friends must therefore each increase their share by 4500 EUR in order to be able to pay the asking price. Calculate the price of the land. [6.4]

(5 pts. for the correct answer)
The economic conditions
Data

- Loan-officer dataset
  - 128 loan officers who passed math test in 2010/02
  - Math score
  - Gender, age, experience, education

- Credit-file dataset
  - Loan applications from 2007/07 - 2010/02
  - First time borrowers only
  - 5,928 loan applications → 3,619 granted loans
Math score

• Score 0 – 100%, > 65% passed the test, 38 loan officers failed (not in sample)

• We group loan officers by numeracy
  • *High*: 90% - 100%
  • *Medium*: 80% - 89%
  • *Low*: 65% - 79%
Risk score and arrears

Kaplan-Meier survival est. 30d arrear over first 24m


Arrears: 30 day arrear within first 24 months

Non-Risky: Risk score = 1 (n=2,757)
Risky: Risk score = 2 (n=816) or 3 (n=46)
Measuring the accuracy of credit assessments

• Accuracy Ratio [0,1]
  • Compares the share of loans classified as Risky which are in Arrears to the share of loans in Arrears

<table>
<thead>
<tr>
<th>Numeracy Level</th>
<th>Loan portfolio 2007 Jul - 2010 Feb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>0.20</td>
</tr>
<tr>
<td>Medium</td>
<td>0.30</td>
</tr>
<tr>
<td>High</td>
<td>0.36</td>
</tr>
</tbody>
</table>

• Estimate discriminatory power of the risk score
  • We estimate $\beta$ separately for loan officers with high, medium & low numeracy

$$Arrears_l = \alpha + \beta \cdot Risky_l + \varepsilon_l$$
Identification (I)

- Numeracy is correlated with other loan officer characteristics
  - Observables: gender, age, experience
  - Unobservables: general cognitive ability, social skills

- We control for observable loan officer characteristics

  \[ Arrears_{i,j} = \alpha + \beta_n \cdot Risky_i + \delta \cdot LO_j + \gamma \cdot X_i + \epsilon_{i,j} \]

- We cannot control for unobservable personal traits
  → Our effect must be interpreted as the joint effect of pure numerical skills and correlated traits (cognitive & social skills)
Identification (II)

- Loans are not randomly assigned to loan officers
  - We would expect the bank to assign specific loan applications to high-numeracy loan officers
  - Most difficult applications ... or most important ones

- We control for loan and borrower characteristics
  - Basic controls: requested loan terms, relationship duration
  - Extended controls: financial ratios, firm age & industry

\[ Arrears_{i,j} = \alpha + \beta_n \cdot Risky_i + \delta \cdot LO_j + \gamma \cdot X_i + \varepsilon_{i,j} \]
The empirical approach

• We estimate the precision of risk scores in predicting arrears for each group of loan officers separately
  • n = high, medium & low numeracy

\[ \text{Arrears}_{i,j} = \alpha + \beta_n \text{Risky}_i + \delta \cdot \text{LO}_j + \gamma \cdot X_i + \epsilon_{i,j} \]

• We compare the estimated coefficients $\beta_n$ across the groups of loan officers

$\beta_{\text{high}} \text{ vs. } \beta_{\text{medium}} \text{ vs. } \beta_{\text{low}}$
### Baseline results

$$Arrears_{i,j} = \alpha + \beta_n \cdot Risky_i + \delta \cdot LO_j + \gamma \cdot X_i + \varepsilon_{i,j}$$

<table>
<thead>
<tr>
<th>Numeracy level</th>
<th>Low (1)</th>
<th>Medium (2)</th>
<th>High (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dep var: Arrear</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risky</td>
<td>0.112**</td>
<td>0.165***</td>
<td>0.249***</td>
</tr>
<tr>
<td></td>
<td>(0.044)</td>
<td>(0.046)</td>
<td>(0.041)</td>
</tr>
<tr>
<td>Mean Arrears</td>
<td>0.058</td>
<td>0.079</td>
<td>0.108</td>
</tr>
<tr>
<td>Observations</td>
<td>1.072</td>
<td>1.225</td>
<td>1.322</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.064</td>
<td>0.100</td>
<td>0.129</td>
</tr>
<tr>
<td>Basic controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Extended controls</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Loan officer controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Branch FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Quarter FE</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Chow test**

col (3) vs. col (1)

$0.14**; p=.02$
## Results by subperiod

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Numeracy level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dep var: Arrear</td>
<td>Low (1)</td>
<td>Medium (2)</td>
</tr>
<tr>
<td>Risky</td>
<td>-0.100 (0.057)</td>
<td>-0.012 (0.048)</td>
</tr>
<tr>
<td></td>
<td>Low (4)</td>
<td>Medium (5)</td>
</tr>
<tr>
<td></td>
<td>0.155*** (0.049)</td>
<td>0.204*** (0.051)</td>
</tr>
<tr>
<td>Mean Arrears</td>
<td>0.092</td>
<td>0.046</td>
</tr>
<tr>
<td>Observations</td>
<td>152</td>
<td>391</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.210</td>
<td>0.173</td>
</tr>
<tr>
<td>Basic controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Extended controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Loan officer controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Branch FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Quarter FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Chow test
- col (3) vs. col (1)
  - 0.23**; p=.05
- col (6) vs. col (4)
  - 0.13**; p=.02
What about loan rejections?

• The analyzed sample of granted loans may be subject to a selection effect

• High numeracy loan officers may have already picked out the worst applicants and rejected their applications outright
  • Could bias our estimates of the effect of numeracy on accuracy downwards

• High numeracy loan officers may reject fewer loans outright, as they are prepared to take more (calculated) risks
  • Could bias our estimates of the effect of numeracy on accuracy upwards...
### Loan rejection decisions

<table>
<thead>
<tr>
<th>Dep var: Rejection</th>
<th>Subsample by numeracy level</th>
<th>Total sample: 2007 Jul - 2010 Feb</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low (1)</td>
<td>Medium (2)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Numeracy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium Numeracy</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln(Requested amount)</td>
<td>0.058***</td>
<td>0.047***</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.010)</td>
</tr>
<tr>
<td>Request in Euro</td>
<td>0.041</td>
<td>0.098***</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
<td>(0.029)</td>
</tr>
<tr>
<td>Time relationship</td>
<td>-0.013*</td>
<td>-0.024**</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>New client</td>
<td>0.495***</td>
<td>0.523***</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.029)</td>
</tr>
<tr>
<td>Mean Rejection</td>
<td>0.322</td>
<td>0.404</td>
</tr>
<tr>
<td>Observations</td>
<td>1,581</td>
<td>2,055</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.425</td>
<td>0.390</td>
</tr>
<tr>
<td>Loan officer controls</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Branch FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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<td>Quarter FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Summary and conclusions

• Loan officers with high numeracy levels are more accurate in assessing the creditworthiness of small business borrowers.

• The effect of numeracy is strongest in the pre-crisis lending boom.

• It may pay to hire high numeracy loan officers, especially in credit booms when it is hard to pick out risky borrowers.
Further results

• No direct effect of gender and experience on accuracy
• BUT... numeracy plays an important role for
  • male loan officers
  • inexperienced loan officers
Mean rejection rate is higher for high numeracy loan officers (42%) and medium numeracy loan officers (40%) than for low numeracy loan officers (32%)